AERMOD IMPLEMENTATION GUIDE
September 27, 2005

This document provides information on the recommended use of AERMOD for particular applications. The following recommendations do not replace the use of experience and judgment in the proper use of dispersion models. As always, advanced coordination with reviewing authorities including the development of modeling protocols is recommended.

SELECTING SURFACE CHARACTERISTICS

If you are using AERMET to prepare the meteorological data for AERMOD, you must input three surface characteristics, the surface roughness $\{z_o\}$, the Albedo $\{r\}$, and the Bowen ratio $\{B_o\}$. When using NWS data for AERMOD, data representativeness can be thought of in terms of constructing realistic PBL similarity profiles. As such, the determination of representativeness will depend on a comparison of the surface characteristics (i.e., z_o, B_o and r) between the NWS site and the source location, coupled with a determination of the importance of those differences relative to predicted concentrations.

The degree to which predicted pollutant concentrations are influenced by surface parameter differences between the application site and the NWS site depends on the nature of the application (i.e., release height, buoyancy, design metric, downwash considerations, etc.). For example, a difference in z_o for one application may translate into an unacceptable difference in the design concentration while for a second, the same difference in z_o may lead to an insignificant difference in design concentration. If the reviewing agency is uncertain as to the representativeness of an NWS site, a site-specific sensitivity analysis may be needed in order to quantify, in terms of expected changes in the design concentration, the significance of the differences in each of the surface characteristics.

If the nearest NWS meteorological site's surface characteristics are determined to NOT be representative of the application site, it may be possible that another nearby NWS site may be representative of both weather parameters and surface characteristics. Failing that, it is likely that site-specific meteorological data will be required.

In defining sectors for surface characteristics, the user should specify a sector no smaller than a 30-degree arc. The expected wind direction variability over the course of an hour, as well as the encroachment of characteristics from the adjacent sectors with travel time, makes it hard to preserve the integrity of very narrow sector characteristics. Thus, the user should apply a weighted average of surface characteristics by surface area within each sector for 3 kilometers upwind. Further information on the definition of sectors for surface parameters is provided in the AERMET user's guide.

Here are some suggestions for determining surface characteristics for specific cases:

Rural sources using rural National Weather Service (NWS) meteorological data: Having found an NWS site to be representative of the application site, the values of the surface parameters at the meteorological site should, in general, be used for constructing AERMOD's meteorological profiles. However, as discussed below, it may be acceptable to use regional or source site values for B_o and r. Conversely, for z_o it is generally preferred to use values from the meteorological site since the magnitude of the measured wind speed is intrinsically linked to surface roughness; that is, the higher the surface roughness the greater the mechanical turbulence and the lower the wind speed for a given amount of kinetic energy in the approach flow.

In general, for low-level releases, local differences in z_o are expected to be considerably more significant than similar differences in either B_o or r. Since the albedo and Bowen ratio are used to determine how much of the incoming radiation is converted to sensible heat flux, they are not a strong influence on the measured winds and for many AERMOD applications, can, in general, be considered more regionally representative. However, as indicated above, this is not the case for z_o. The roughness length directly affects the profiling of the measured wind speed and therefore should generally be associated with the area surrounding the meteorological site.

Urban sources using rural NWS meteorological data: When modeling an urban source, the urban algorithms in AERMOD are designed to perturb the characteristics of the flow as measured from an adjacent rural area. Therefore, a rural NWS meteorological site that is being used for an urban source should be representative of the rural area that is adjacent to the urban area in which the source is located and must pass the representativeness tests described earlier. Then, the values of the surface parameters (z_o, B_o and r) from the rural meteorological site location can be used for constructing meteorological profiles that are appropriate for the urban source location. This is accomplished by including the "URBANOPT" and the "URBANSRC" keywords in the AERMOD control file.

Urban sources using urban NWS meteorological data: Most airports are located far enough away from the urban center to be considered rural settings. However, for NWS stations located within the urban area, the basic approach for choosing surface characteristics is similar to that used for rural applications using rural NWS data. That is, values for the surface parameters (z_o, B_o and r) should be taken the area surrounding the NWS site. However, since profiles constructed from the urban surface measurements will not fully reflect the actual turbulence or the expected development of a nighttime urban mixing height, the user will also need to select AERMOD's URBAN option.

Urban sources using urban site-specific meteorological data: In most cases site-specific data collected within the urban area should be treated in a manner similar to urban NWS data. That is, the surface characteristics should be selected from the meteorological site and AERMOD's urban options should be applied. Furthermore, in order to avoid double counting the effects of the urban heat island, on-site measured turbulence data should NOT be used when applying AERMOD's urban option. However, if the on-site data is of high enough quality and extent, then it may be possible on a case-by-case basis to apply AERMOD without use of the URBAN option. That is, to apply AERMOD in an urban setting without selecting its urban option the meteorological data used must be sufficient to fully define the profiles of wind, temperature and turbulence, as well as including estimates of the urban nighttime mixing height.

URBAN DETERMINATION

For AERMOD applications, Appendix W guidance (refer to section 8 of Appendix W - "Guideline on Air Quality Models" should be used in determining the urban/rural status of a source.

Selecting population data for AERMOD's urban mode: For relatively isolated urban areas, the user may use published census data corresponding to the Metropolitan Statistical Area (MSA) for that location. For urban areas adjacent to or near other urban areas, or part of urban corridors, the user should attempt to identify that part of the urban area that will contribute to the urban heat island plume affecting the source. If this approach results in the identification of clearly defined MSAs, then census data may be used as above to determine the appropriate population for input to AERMOD. For situations where MSAs cannot be clearly identified, the user may determine the extent of the area, including the source(s) of interest, where the population density exceeds 750 people per square kilometer[1]. The combined population within this identified area may then be used for input to the AERMOD model. The user should bear in mind that the urban algorithms in AERMOD are dependent on population to the one-fourth power, and are therefore not highly sensitive to variations in population. Population estimates to two significant figures should be sufficiently accurate for application of AERMOD.

MODELING SOURCES IN GENTLY DOWN-SLOPING TERRAIN

For all situations in which there is a difference in elevation between the source and receptor, AERMOD simulates the total concentration as the weighted sum of 2 plume states[2]: 1) a horizontal plume state (where the plume's elevation is assumed to be determined by release height and plume rise effects only, and thereby allowing for impingement if terrain rises to the elevation of the plume); and, 2) a terrain-responding plume state (where the plume is assumed to be entirely terrain following).

For cases in which receptor elevations are lower than the base elevation of the source (i.e., receptors that are down-slope of the source), AERMOD will predict concentrations that are less than what would be estimated from an otherwise identical flat terrain situation. Therefore, in the case of gently down-sloping terrain, where expert judgment suggests that the plume is terrain following (e.g., down-slope gravity flow), AERMOD will tend to underestimate concentrations. This situation has been examined for low-level area sources by Sears (2003)[3]. Sears has shown

[1] Irwin, J.S., 1978. Proposed Criteria for Selection of Urban Versus Rural Dispersion Coefficients. (Draft Staff Report), Meteorology and Assessment Division, U.S. Environmental Protection Agency, Research Triangle Park, NC. (Docket No. A-80-46, II-B-8)

[2] Cimorelli, A. J., S. G. Perry, A. Venkatram, J. C. Weil, R. J. Paine, R. B. Wilson, R. F. Lee, and W. D. Peters, 2004. AERMOD: Description of Model Formulation, EPA-454/R-03-004.

[3] Sears, C., 2003. Letter to Docket No. A-99-05 Availability of Additional Documents Relevant to Anticipated Revisions to Guideline on Air Quality Models Addressing a Preferred General Purpose (flat and complex terrain) Dispersion Model and Other Revisions (Federal Register / Vol. 68, No. 173 / Monday, September 8, 2003).

that as terrain slope increases the ratio of AERMOD to ISC (which assumes flat terrain in this situation) estimates decrease substantially.

To avoid this situation, it may be reasonable, in the case of gently down-sloping terrain, to assume flat, level terrain, especially for low-level sources. This decision should be made on a case-by-case basis, relying on the modelers experience and knowledge of the surrounding terrain and other factors that affect the air flow in the study area.

CAPPED AND HORIZONTAL STACKS

For capped and horizontal stacks that are NOT subject to building downwash influences a simple screening approach (Model Clearinghouse procedure for ISC) can be applied. That is, an effective stack diameter may be used to maintain the flow rate, and hence the buoyancy, of the plume, while suppressing plume momentum by setting the exit velocity to 0.001 m/s. To appropriately account for stack-tip downwash, the user should first apply the non-default option of no stack-tip downwash (i.e., NOSTD keyword). Then, for capped stacks, the stack release height should be reduced by three actual stack diameters to account for the maximum stack-tip downwash adjustment while no adjustment to release height should be made for horizontal releases.

Capped and horizontal stacks that are subject to building downwash, should not use an effective stack diameter to simulate the restriction to vertical flow since the PRIME algorithms use the stack diameter to define the plume radius which, in turn, is used to solve conservation laws. The user should input the actual stack diameter and exit temperature but set the exit velocity to a nominally low value, such as 0.001 m/s. This approach will have the desired effect of restricting the vertical flow while avoiding the mass conservation problem inherent with effective diameter approach. The approach suggested here is expected to provide a conservative estimate of impacts. Also, since PRIME does not explicitly consider stack-tip downwash, no adjustments to stack height should be made.

AERMAP DEM ARRAY AND DOMAIN BOUNDARY

Section 2.2.1 of the AERMAP User's Guide states the DEM array and domain boundary must include all terrain features that exceed a 10% elevation slope from any given receptor. The 10% slope rule may lead to excessively large domains in areas with considerable terrain features (e.g., fjords, successive mountain ranges, etc). In these situations, the reviewing authority may make a case-by-case determination regarding the domain size needed for AERMAP to determine the critical dividing streamline height for each receptor.

MANUALLY ENTERING TERRAIN ELEVATIONS IN AERMAP

AERMAP version 03107 does not have the capability of accepting hand-entered terrain data (xyz data). AERMAP can accept terrain data from DEM files only. Therefore, if DEM data is not available, for a particular application, terrain elevations will need to be entered manually in a form that mimics the DEM data format. Instructions for how to accomplish this can be found on the SCRAM web site http://www.epa.gov/scram001/ in a document titled "Inputting XYZ Data Into AERMAP."

USE OF AREA SOURCE ALGORITHM IN AERMOD

Because of issues related to excessive run times, the approach that AERMOD uses to address plume meander has not been implemented for area sources. As a result, concentration predictions for area sources may be overestimated under very light wind conditions (i.e., $u \ll 1.0$ m/s). In general, this is not expected to be a problem for meteorological data collected using standard wind instruments; instrument thresholds are generally too high. This problem has arisen when data from a gridded meteorological model was used to drive AERMOD. Meteorological grid models can at times produce extremely light winds. During such conditions time averaged plumes tend to spread primarily as a result of low frequency eddy translation rather than eddy diffusion. AERMOD treats this meander effect by estimating the concentration from two limiting states: 1) a coherent plume state that considers lateral diffusive turbulence only (the mean wind direction is well defined) and 2) a random plume state (mean wind direction is poorly defined) that allows the plume to spread uniformly, about the source, in the x-y plane. The final concentration predicted by AERMOD is a weighted sum of these two bounding concentrations. Interpolation between the coherent and random plume concentrations is accomplished by assuming that the total horizontal "energy" is distributed between the wind's mean and turbulent components.

In order to avoid overestimates for area sources, during light wind conditions, it is recommended that, where possible, a volume source approximation be used to model area sources. This approach can be applied with confidence for situations in which the receptors are displaced from the source. However, for applications where receptors are located either directly adjacent to, or inside the area source, AERMOD's area source algorithm will need to be used. For these circumstances, caution should be exercised if excessive concentrations are predicted during extremely light wind conditions. On a case-by-case basis, the reviewing authority should decide whether such predictions are unrealistic. One possible remedy would be to treat such hourly predictions as missing data.

It is EPA's intention to correct this problem. A version of AERMOD that includes meander for area sources will be developed as soon as practicable.